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PHYSIOLOGICAL DETERMINANTS OF LOAD BEARING CAPACITY

U S ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE
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This study identifies some of the physiological determinants of load bearing capacity. Although it is reasonable to assume that maximal aerobic capacity (VO_2) is an important determinant of load bearing ability, research implicating the importance of muscular strength and endurance of the lower extremities in load bearing activity has not been reported. To address this deficiency, 49 infantrymen were measured for: 1) aerobic capacity, 2) muscular strength of the quadriceps and hamstrings 3) muscular endurance of the quadriceps and hamstrings and 4) body composition. Following these measures, the infantrymen made a maximal effort 10-mile road march with battle dress equipment (total wt = 18 $\pm$ 1 kg). Absolute VO_2 was a significant correlate of performance time ($p \leq .01$). However, hamstring muscle strength was also a significant factor ($p < .003$) and, emerged as the only significant predictor of marchtime (multiple R=.45; r=.21) when step-wise multiple regression was performed. Dividing the group into 3 performance categories according to road marchtime (excellent=1s.d. < mean, average = $\pm$ 1s.d. about mean, and poor = 1s.d. > mean) revealed significant differences

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between the excellent and poor groups with respect to hamstring muscle strength ($p < .02$) and $\dot{V}O_2$ ($p < .06$). These data suggest that hamstring muscle strength may be an important determinant of prolonged load bearing performance. Further research may elucidate the degree to which aerobic capacity, muscle strength, and other physiological variables independently and/or interactively influence load bearing capacity.

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DISCLAIMERS

Human subjects participated in this study after giving their free and informed consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research.

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Technical Report

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by

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FOREWORD

This study originated from a collaboration between the Division Surgeon's Office, 101st Airborne Division (Air Assault) and the U.S. Army Research Institute of Environmental Medicine. Two of the authors of this report became interested in the determinants of load bearing capacity following completion of Air Assault School training. This report represents a pilot study of this interest.

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ABSTRACT

This study identifies some of the physiological determinants of load bearing capacity. Although it is reasonable to assume that maximal aerobic capacity (VO_2) is an important determinant of load bearing ability, research implicating the importance of muscular strength and endurance of the lower extremities in load bearing activity has not been reported. To address this deficiency, 49 infantrymen were measured for: 1) aerobic capacity, 2) muscular strength of the quadriceps and hamstrings 3) muscular endurance of the quadriceps and hamstrings and 4) body composition. Following these measures, the infantrymen made a maximal effort 10-mile road march with battle dress equipment (total wt = 18 ± kg). Absolute VO_2 was a significant correlate of performance time ($p<.01$). However, hamstring muscle strength was also a significant factor ($p<.003$) and, emerged as the only significant predictor of marchtime (multiple $r=.45$; $r^2=.21$) when step-wise multiple regression was performed. Dividing the group into 3 performance categories according to road marchtime (excellent=1s.d.<mean, average= ± 1s.d.about mean, and poor=1s.d.>mean) revealed significant differences between the excellent and poor groups with respect to hamstring muscle strength ($p<.02$) and, VO_2 ($p<.06$). These data suggest that hamstring muscle strength may be an important determinant of prolonged load bearing performance. Further research may elucidate the degree to which aerobic capacity, muscle strength, and other physiological variables independently and/or interactively influence load bearing capacity.

PHYSIOLOGICAL DETERMINANTS OF LOAD BEARING CAPACITY

INTRODUCTION

One approach to improvement of load bearing performance of infantry soldiers is through the reduction of the loads they carry. Thus, lightening the soldiers' load has recently become a topic of much interest(1). However, tactical and logistical requirements of battle limit the degree to which this strategy is possible, eventually resulting in diminishing return. Moreover, with the advent of so-called "light" divisions and emphasis upon mobility of forces on the battlefield, even greater demand will be placed upon the individual soldiers' load bearing capacity. Whereas in standard divisions cargo vehicles transport many supplies, light division tactics will require the individual soldier to assume more of the load bearing burden associated with combat(2). However, the physiological determinants of load bearing capacity in the individual soldier and their relative contribution to this capacity have not been well defined.

Previous studies of load bearing have focused primarily on energy cost and relative intensities of self-paced tasks(3,4,8,9). Maximal oxygen uptake (VO_2max) is often used to predict performance times in distance running, suggesting VO_2max may be an important component to success in maximal performance load bearing tasks as well. This assumption is supported by energy cost measurements made while walking on treadmills with differing loads placed on the back(10). These studies indicate that so long as the load is axially placed (i.e. close to the spine), the additional energy cost attributable to the load carried is approximately equivalent to the same

weight distributed over the body as subcutaneous fat. Since the energy cost of moving a given load or "dead weight" is relatively constant, a large individual with greater absolute oxygen consumption capacity (VO_2max) will experience less reduction in relative VO_2max while load bearing than a small individual (assuming body composition is similar), presumably enabling superior performance by the larger individual. Furthermore, individuals tend to "choose" identical relative exercise intensities regardless of their absolute VO_2max when asked to perform sustained load-bearing tasks(5,6,7). Thus, individuals with less body fat, as well as those for whom the load carried represents a smaller percentage of overall body weight, and those who have generous aerobic capacities may be postulated to possess superior load bearing capacity.

Strength or alactic anaerobic power may be quantified as the maximal force that can be generated in a brief (less than 5 seconds) maximal effort, while muscular endurance or lactic anaerobic power refers to exercise capacity characterized by more prolonged (5 to 60 second) high intensity effort(11). This definition of muscular endurance is different than the colloquial notion of "endurance", which is typified by extremely prolonged (15 minutes or more), relatively low intensity effort. Although not previously studied, strength and endurance of the lower extremity muscles are undoubtedly important for load bearing capacity. For example, if the hamstring or quadriceps muscles of two soldiers have similar endurance at the same relative level of load, but one soldier's muscle is much stronger (for example, by virtue of larger cross-sectional area), it is reasonable to expect the weaker soldier's muscle to fatigue sooner if the same absolute load is employed. Conversely, if two soldiers have equal muscle strengths, but one has more endurance at the same

absolute level of load, the soldier with more muscular endurance should have greater fatigue resistance. Although training status, muscle fiber characteristics, and neural factors may modify these considerations (11), in general, greater muscle strength and endurance of the hamstrings and quadriceps are likely to be beneficial with respect to load bearing performance. Furthermore, the relative contribution of upper versus lower extremity muscular strength/endurance to load bearing performance is unknown.

Since it is not known which physiologic determinants and to what degree their interaction influence load bearing capacity, this study was undertaken to determine the relative contribution of size, body composition, aerobic capacity, muscular strength, and muscular endurance on a 10-mile maximal performance march while carrying an 18 kg load. In this study only lower extremity muscular strength and endurance measures were considered.

METHODS

Test Subjects.

Test subjects for this study were volunteers from A,C, and D Companies, 1/502 Infantry, 2nd Brigade of the 101st Airborne Division (Air Assault), Ft. Campbell, KY. Company commanders were apprised of the study, and participation was encouraged for all soldiers. The soldiers were asked to participate in the study only if willing to provide their "best effort". Of 65 original subjects briefed, 56 volunteered for the study, gave their informed consent and were medically screened. These 56 soldiers were physiologically tested during the first week of the study. Following a

weekend of rest, forty nine (of 56) subjects voluntarily returned for the 10-mile performance march.

Load items.

The carried load list for the march is found in Appendix A. Soldiers were required to wear Battle Dress Uniforms (BDU) with combat boots. Additionally, they were asked to wear their steel helmets and support their rifles either, at port-arms position or in one hand (as opposed to slinging it over the shoulder). All items not directly worn or attached to the equipment belt were transported inside the field pack which was positioned high on the back. The combined weight carried by all soldiers thus totalled 18 ± 1 kg (40 +/- 2 lbs). Extra canteens filled with water were added for weight if required, and soldiers were asked not to drink from these "ballast" items. Soldiers were weighed with and without full pack to verify equipment weight and make appropriate adjustments. Post-run weights were obtained to verify that the load was carried for the full distance as well as to detect hypohydration status.

Course.

All soldiers had performed a 10 mile march over the same course within the past 2 years by successfully completing Air Assault School, which requires the 10 mile march as a prerequisite to graduation. The primary differences between the Air Assault School march and the current study were the load carried (10kg vs 18 kg) and the effort required (liberal time requirement versus maximal effort). The course consisted primarily of an asphalt covered walkway except for the first two miles and the last mile which were vehicular

roads. The terrain was primarily flat except for a steep hill between miles 2 and 3, and rolling hills between miles 7 and 9. Water stops were provided at miles 2,4,6, and 8, and soldiers were encouraged to drink at least 4 oz. of water at every stop. A field ambulance with medics aboard followed the soldiers over the course, and study monitors were positioned at 2 mile intervals for the purpose of verification of passage and assistance to soldiers, if required.

Physiologic Testing.

Body heights and body weights were recorded during the first week of testing. Aerobic power was assessed by the determination of maximal oxygen uptake (VO_2max) utilizing a discontinuous uphill treadmill running protocol(12). The procedure began with an initial warm-up run at 6 mph and 0% grade for 6 minutes, followed by a 5-10 minute rest period. Two to four additional runs were performed, each 3-4 minutes in length and interrupted by rest periods. The runs progressively increased in exercise intensity by increasing the speed and/or grade of the treadmill. During the last minute of each run, three 30-second aliquots of expired air were collected into Douglas bags through a mouthpiece and low-resistance breathing valve. A plateau in oxygen consumption with increasing intensity was considered indicative of VO_2max. A plateau is defined as less than a 2 ml increase of oxygen uptake with a 2% increase in grade. Gas volumes were measured by a Collins 120 liter chain-compensated spirometer. The aliquots of expired air were analyzed for oxygen and carbon dioxide fractions with an Applied Electrochemistry fuel cell (MDL S-3A) and a Beckman LB-2 infrared carbon dioxide analyzer, respectively. Both gas analyzers were calibrated using primary certified gas

standards (Matheson Gas Company, Gloucester, MA) which were checked for accuracy against calibrated cylinders and daily outside air analyses.

Lower extremity dynamic strength of the right leg (hamstring and quadriceps) was measured with the Cybex II dynamometer as described by Caizzo et al(13). Subjects were seated on a test bench with the right leg strapped to the lever arm of the Cybex dynamometer so that the input axis was in alignment with the subjects' knee joint for quadriceps measures. For the hamstring measures the subjects lay face down on a padded bench with the dominant leg attached to the lever arm of the dynamometer. Limb movement was isolated by means of straps across the chest, hips, and thighs while seated; and with straps across the back, buttocks, and loins while recumbent. Vertical and horizontal displacement was, therefore, held constant in order to ensure machine-subject alignment. The subjects were instructed to perform 3 consecutive maximal contractions at angular velocities of 60, 180, and 300 degrees/second. From the average of 3 contractions at each angular velocity, peak torque was calculated for both the hamstring and quadriceps muscles.

Lower extremity endurance (hamstring and quadriceps) was also measured with the Cybex II dynamometer as described by Thorstensson(14). Subjects were prepared in a manner identical to that for strength testing. The subjects were instructed to perform 50 consecutive maximal contractions at an angular velocity of 180 degrees/second. From these 50 contractions, mean torque and percent peak torque decrement values were calculated for the hamstring and quadriceps muscles.

Body composition was determined by hydrostatic methods. Underwater weighing was conducted in a 4x4x5 foot aluminum tank filled with water maintained at 37°C. An aluminum chair was attached to a load cell (Ametek)

sensitive to 10 grams, and both were suspended from a stainless steel trapeze. Output from the load cell was fed through an analog-to-digital converter to a Hewlett-Packard desk top calculator which was programmed to store weights for subsequent determinations of stable underwater weight and body composition parameters. The method for determining body density was similar to that described by Goldman and Buskirk(15). Subjects were underwater weighed clothed in a swimsuit while in a post-absorptive state. Underwater weights were obtained by having the subjects, while submerged, blow out forcefully to their residual lung volume at which time their weights were determined. Approximately 7 trials were usually required by each subject in order to obtain a stable measure of body density. Residual lung volume, required for the calculation of body composition was determined prior to the underwater weighing procedure. A simplified oxygen rebreathing technique was utilized(16). Each soldier assumed a sitting position during the residual lung volume determination, which was similar to the posture utilized during the underwater weighing procedure. If there was greater than a 150 ml difference between 2 trials, a third measure was taken, and the mean of the two closest values was used.

RESULTS

Subject characteristics for the 49 infantrymen who participated in this study are presented in Table 1.

TABLE 1. SUBJECT CHARACTERISTICS (n=49)

VARIABLE	MEAN (SD)	RANGE
Age	21.8 (3.0)	(18.0 - 32.0)
Height(cm)	176.2 (6.7)	(155.0 - 190.5)
Weight(kg)	73.5 (9.8)	(53.2 - 105.4)
VO_2max(ml/kg/min)	56.9 (5.2)	(45.0 - 69.0)
Body Fat(%)	15.5 (6.3)	(5.0 - 33.7)

Table 2 presents the mean marchtime for the overall group and the mean marchtime by level of performance (excellent=1 SD faster than overall mean, average=within 1 SD above and below overall mean, poor=1 SD slower than overall mean).

TABLE 2. 10-MILE ROAD MARCHTIME (hours)

GROUP	MEAN (SD)	RANGE
Overall	2.42 (0.32)	(1.72 - 2.87)
Excellent*	1.94 (0.13)	(1.72 - 2.07)
Average**	2.50 (0.16)	(2.14 - 2.74)
Poor***	2.83 (0.03)	(2.79 - 2.87)

* >1 SD faster than overall group mean

** within 1 SD above and below overall group mean

*** >1 SD slower than overall group mean

Appendix B lists the simple Pearson product-moment correlation coefficients for group performance time and the primary physiological measures considered in this study.

In Table 3, results of simple correlations of maximal aerobic capacity and hamstring peak torques at 60°, 180°, and 300° with marchtime are presented with respective p-values. The table identifies the variables which individually best correlate with performance times.

TABLE 3. SIGNIFICANT CORRELATIONS WITH 10-MILE MARCHTIME:

VARIABLE	r	r^2	p-value
FLX180*	-.42	.18	<.003
VO_2L**	-.37	.14	<.01
FLX300***	-.34	.12	<.01
FLX60****	-.34	.12	<.01

*hamstring peak torque at 180°/second (strength measure)

**maximal oxygen uptake in liters/minute (aerobic capacity measure)

***hamstring peak torque at 300°/second (strength measure)

****hamstring peak torque at 60°/second (strength measure)

Despite the "significant" correlations, due to high colinearity of these variables to one another, only FLX180 emerged as an independent predictor of marchtimes when step-wise multiple regression was performed (multiple $r = -.45$, $r^2 = .21$). The r^2 indicates the percentage of variance in marchtimes accounted for by the particular variable. Thus, eighteen percent of the variance in marchtime is accounted for by hamstring strength. Developing regression equations for the 3 performance groups separately produced no significant ($p<.05$) results.

Tables 4 and 5 are analyses of variance (ANOVA) by performance group (excellent, average, poor). ANOVA was performed between the three groups in

an attempt to find the variables differing significantly between groups. The only variables found to differ between groups were FLX180 and VO_2L. Tukey's post-hoc test determined the significant ($p<.05$) difference to occur between excellent and poor groups for both FLX180 and VO_2L. Ninety-five percent confidence intervals for FLX180 values among the 3 groups (newton-meters) are: excellent (59.9 - 74.2), average (55.1 - 65.9), poor (42.8 - 57.2). Similar intervals for VO_2 values among the groups (liters/minute) are: excellent (4.03 - 4.70), average (3.99 - 4.35), poor (3.51 - 4.13). For the VO_2 confidence limits, excellent and poor group values overlap slightly in accord with the overall F value which reached marginal significance ($p=.055$).

TABLE 4. ANALYSIS OF VARIANCE: FLX 180 BY PERFORMANCE GROUP

SOURCE	SS	df	MS	F	p
Between groups	1350.5	2	675.3	4.2*	.021
Within groups	7252.5	45	161.2		
Total	8603.0	47			

$^{*}F_{(2,45)}=3.21$

TABLE 5. ANALYSIS OF VARIANCE: VO_2L BY PERFORMANCE GROUP

SOURCE	SS	df	MS	F	p
Between groups	1.40	2	0.70	3.09*	.055
Within groups	10.41	46	0.23		
Total	11.81	4			

$^{*}F_{(2,46)}=3.20$

DISCUSSION

The carried load of 18 kg. was chosen after much deliberation. Although in some respects the load was too light to represent the burden expected in actual combat, the intention was to employ a weight which could allow the soldiers to run if they were capable of doing so. Levine et al., in a prior study of self-paced load carriage, found that energy expenditure between fit and unfit subjects did not differ significantly, and hypothesized that fit subjects were limited by their inability to walk any faster(7). The distance of 10 miles was employed because it was hoped that muscular fatigue would emerge as a significant factor in a prolonged march, yet not be confounded by the issue of substrate availability (i.e. glycogen depletion). However, considering the mean marchtime of 2.4 hours, glycogen availability could have differentially affected the results.

The subject pool apparently consisted of soldiers who were not highly trained despite their Air Assault status. The relative VO_2max and body composition characteristics of the group averaged 56 ml/kg/min and 15% respectively--values which are consistent with moderately high fitness level. However, these values do not ascertain whether the group was highly trained or not. In fact, degree of body fatness is negatively correlated with relative VO_2max, especially in subjects who are not highly trained. Vogel (1985) reported a correlation coefficient of -0.52 in a group of soldiers (n=309) who were not highly trained(11). The corresponding coefficient for the current

study group is -0.51. This correlation tends to disappear in groups who are well trained and hence more homogeneously fit and lean. Thus, the present study appears to have examined a relatively heterogeneous and not particularly highly trained group. In fact, this was the case since this group of soldiers had recently returned from an extended field exercise and therefore, were relatively detrained with respect to load bearing performance. During field exercises, daily organized physical training and road marches are usually curtailed. Conclusions extended to a more homogeneous and/or highly trained group of soldiers (e.g. Delta Force, Rangers) therefore, should be made with caution.

Perhaps the most interesting finding to emerge is the importance of a "strength" (high intensity, brief duration) measure in prediction of an ostensible "prolonged" (lower intensity, longer duration) event (10-mile march). In many sports, strength measures often bear little relationship to prolonged performance capacity. Extreme examples may be found in the elite distance runner, possessing aerobic capacity, but little strength, and powerlifters, having great strength, but little aerobic capacity. In the present study, apriori, the strongest relationship would have been expected for marchtime and an endurance capacity measure i.e. VO_2L (aerobic endurance) or perhaps, mean torque (muscular endurance). However, this was not the case.

Presumably, in individuals not selectively trained to extreme ends of the strength-endurance continuum, strength and endurance would be more highly correlated whether individuals are fit or not. This appears to be the case in the current study which demonstrated a good correlation (r=.66) between aerobic capacity (VO_2L) and hamstring strength(FLX180). If load bearing capacity was improved by selective training on the strength end of the

spectrum, this high correlation would likely be reduced. One issue then, with respect to improvement of load bearing capacity, is determination of the optimal strength to endurance ratio for best performance.

It is the opinion of the investigators that the hamstring muscles are, perhaps, with the notable exception of sprinters and football linemen, one of the most undertrained muscle groups of the body with respect to strength. Since the hamstring muscles (hip extensors, knee flexors) and quadriceps muscles (hip flexors, knee extensors) are utilized to different degrees during activities such as walking, running, and sprinting, it may be difficult to determine experimentally which set of muscles are most important with respect to load bearing performance. In fact, relative importance is likely to vary according to speed of the march, which itself depends upon the load carried and distance covered. However, given the training status of the test subjects, the load, and distance employed in this study, it appears that hamstring strength is a more important physiologic variable. If selective strength training of the hamstring muscles could significantly improve specific load bearing performance (and this could be demonstrated in future training trials), changes in the current methods used by the Army for training of load bearers may be advisable. Also, a major performance aspect of the light division concept could be enhanced.

Another important issue is that of specificity. The question naturally arises as to why muscle strength at 180°/sec was more specifically correlated to this load bearing performance. That is, why wasn't muscle strength at 60°/sec or 300°/sec also significantly correlated with marchtime. Although the matter is not settled by any means, it is possible that the average marchtime of 2 hours and 24 minutes (14.5 minutes/mile) required angular

velocities at the knee which closely approximate Cybex II speeds of 180°/sec. If so, then the results are expected since training is well known to have requirements of specificity(8). Perhaps, then, in selectively training for a load bearing performance, it will be important to take into account commonly used rates of march, in order to optimally train the hamstrings for specificity of effort.

The discussion of specificity should also include the issue of intended functional use of the muscle itself. Since the criterion task of the road march required dynamic use of lower extremity muscles, dynamic strength testing may have been an appropriately-specific strength measure. However, Cybex equipment measures isokinetic dynamic strength while marching is unlikely to utilize lower extremity muscles in a strictly isokinetic manner(17). Similar issues of specificity, however, could be raised against the appropriateness of isotonic strength measures as well. In future studies of load bearing, isometric strength and endurance of some muscles should be measured. For example, the back extensor and abdominal muscles which, in concert, function to keep the torso upright during load bearing are probably in varying states of isometric contraction during a road march with loads. Thus, depending upon the load carried and the demand characteristics of the terrain and distance covered, isometric strength and endurance of the back extensors and abdominal muscles may be important variables.

The issue of motivation must be discussed as a potential confounder in the current study. It is clear that in any performance trial the level of motivation (and thus the level of performance achieved relative to potential) may vary considerably between subjects. It is not clear that motivation is necessarily distributed in random fashion among test subjects. In fact, this

is likely not to be the case; especially when, soldiers may march together and thereby assist (or impede) each others' performances. Thus, the observed associations between performance times and physiological variables may be confounded. In an attempt to minimize the effect of motivation as a confounder in the current study, individuals were asked not to march together and to give their best individual efforts. Despite this admonition, teamwork undoubtedly did occur. Among individuals toward the back of the pack some clustering of marchtimes was observed.

Further control of confounding by motivation might be accomplished by use of continuous heart rate monitoring during the performance march for the purpose of identifying relative exertional levels. In this manner, investigators may determine at what percent of maximal capacity a subject is functioning. One problem with this approach has been the lack of acceptable monitors (i.e. accuracy and bulkiness). Another, perhaps, more important issue is that individual ability to function at a high percent of maximal aerobic capacity near the lactate threshold differs somewhat among subjects as a function of genetic endowment and training level(18). However, gross lack of effort could easily be detected with heart rate monitors and data edited accordingly. Oxygen consumption-heart rate relationships could also be established in advance of performance trials by treadmill protocol. The determination of lactate threshold with respect to the aforementioned relationship may also be useful in ascertainment of relative exertional level. Psychologists and neurobehaviorists could develop questionnaires designed to identify motivational levels prior to performance trials. Thus, individuals could be matched with respect to motivation during design or analysis phases of the study and confounding controlled. Finally, the use of a relatively

homogeneous, highly-trained group such as Delta Force or the Rangers may represent another informative study population. Although it may be noted that such a study would not generate information which is necessarily generalizable to the "average" infantryman, the control of motivation may allow for a more precise estimation of the true association between physiologic variables and performance.

Motivation may be improved by the presence of the soldiers' first sergeants and/or commanders. Participation by the chain of command in the performance trial, while desirable, may not be feasible. Incentives such as weekend passes or awards might also be utilized.

To standardize the oxygen cost of load bearing performance to factors such as load carried, oxygen-consuming lean body mass (LBM), and body weight, the following variables were developed:

1) Adjusted $VO_2 1$ = $VO_2 L$ x 1000/(Body weight + 18 kg)

2) Adjusted $VO_2 2$ = $VO_2 L$ x 1000/(LBM + 18 kg)

Simple correlation of marchtime to adjusted $VO_2 1$ produced $r=.33$ ($p<.01$). However, the use of these variables in a regression equation contributed no improvement in the amount of variance accounted for in marchtimes over that provided by FLX180 or $VO_2 L$ alone.

Future studies of load bearing capacity should consider the use of differing loads and march distances for performance trials. Confounding due to motivation must be controlled by use of highly motivated groups, or by monitoring of physiological intensity. However, some cautions should be observed. The distance of 10 miles at maximal effort may nearly deplete

muscle glycogen. Glycogen depletion could adversely affect performance time and confound the impact of other measured physiologic variables, if not accounted for. Hypohydration greater than 5% can also affect performance time significantly and may occur with greater likelihood during longer march distances, and under warm conditions. The strength of other lower extremity muscles, such as the gluteus and gastrocnemius, should be correlated with load bearing performance. Furthermore, the role of upper body muscles (including back extensors) in load bearing should be examined. The isometric strength (in contrast to dynamic strength measured in this study) of muscles such as the back extensors may be a profitable future area of inquiry.

APPENDIX A

Load Item List

1) Field jacket with liner
2) Cap, insulated helmet
3) Sock, wool cushion (1 pair worn, 1 pair in pack)
4) Identification tags ("dog tags")
5) Belt, individual equipment
6) Canteen, water plastic (2,filled) with cover & cup
7) Case, field first aid w/dressing
8) Case, small arms (2)
9) Overshoe, rubber man's
10) Poncho, coated nylon
11) Suspenders, field pack
12) Shelter half
13) Entrenching tool with cover
14) Scarf, neckware man's wool
15) Fatigue uniform
16) Boots, combat black
17) Helmet, ground troops with head & neck bands, liner, & chin strap
18) M-16 Rifle
19) Pack, field, large LC-1 (without frame)

APPENDIX B

CORRELATION MATRIX OF ALL MEASURED PHYSIOLOGICAL VARIABLES

	HT	BW	%FAT	LBM	VO2ML	TIME	EX60	EX300	FL60	FL300	EX180	EXMT	EXDEC	FL180	FLMT	FLDEC	VO2L
HT	1.00																
BW	.56	1.00															
%FAT	-.10	.51	1.00														
LBM	.72	.82	-.07	1.00													
VO2ML	-.09	-.48	-.51	-.15	1.00												
TIME	-.31	-.15	.15	-.30	-.24	1.00											
EX60	.45	.39	-.27	.65	.07	-.21	1.00										
EX300	.36	.39	-.29	.64	-.07	-.14	.71	1.00									
FL60	.55	.48	-.13	.66	.00	-.34	.70	.58	1.00								
FL300	.37	.37	.11	.52	.04	-.34	.53	.53	.81	1.00							
EX180	.45	.42	-.29	.67	-.09	-.13	.74	.89	.58	.51	1.00						
EXMT	.39	.40	-.25	.64	.00	-.20	.55	.82	.43	.43	.82	1.00					
EXDEC	.18	.02	-.10	.10	-.10	-.04	.36	.23	.20	.16	.28	.10	1.00				
FL180	.49	.52	.00	.63	.11	-.42	.58	.49	.84	.78	.45	.38	.19	1.00			
FLMT	.36	.25	-.17	.43	.24	-.25	.56	.53	.77	.84	.48	.42	.13	.73	1.00		
FLDEC	-.09	-.25	-.17	-.16	.18	-.09	.02	-.03	.12	.11	-.04	-.02	-.10	-.01	-.05	1.00	
VO2L	.54	.70	.14	.74	.29	-.37	.51	.37	.55	.45	.38	.43	.05	.66	.49	-.08	1.00
ADVO2	.09	.20	.40	.06	.95	-.33	.23	.06	.18	.18	.05	.13	-.10	.30	.37	.14	.56

HT, height; BW, body weight; %FAT, percent fat; LBM, lean body mass; VO2ML, relative maximal oxygen uptake; TIME, marchtime; EX60,300,180 - extension peak torque at 60,300, & 180 degrees per second; FL60,300,180 - flexion peak torque at 60,300,180 degrees per second; (EX&FL)MT,PT DEC - mean, peak, and decrement torque from Thorstensson cybex test; VO2L, absolute maximal oxygen uptake; ADVO2, maximal oxygen uptake adjusted for load weight.

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